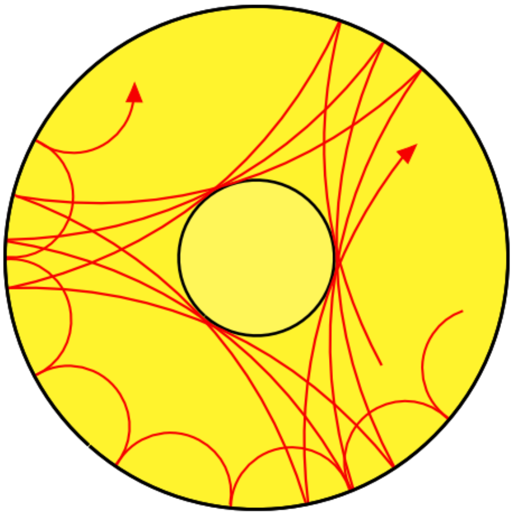
Asteroseismology



Different oscillation modes penetrate to different depths inside a star.

Asteroseismology (from Greek ἀστήρ, *astēr*, "star"; σεισμός, *seismos*, "earthquake"; and -λογία, *-logia*) also known as **stellar seismology**[1][2] is the science that studies the internal structure of pulsating stars by the interpretation of their frequency spectra. Different oscillation modes penetrate to different depths inside the star. These oscillations provide information about the otherwise unobservable interiors of stars in a manner similar to how seismologists study the interior of Earth and other solid planets through the use of earthquake oscillations.

Asteroseismology provides the tool to find the internal structure of stars. The pulsation frequencies give the information about the density profile of the region where the waves originate and travel. The spectrum gives the information about its chemical constituents. Both can be used to give information about the internal structure. Asteroseismology effectively turns tiny variations in the star's light into sounds.[3]

In addition, asteroseismology helps to constrain the other characteristics of stars such as mass and radius more accurately than basic brightness measurements.[2]

1 Oscillations

The oscillations studied by asteroseismologists are driven by thermal energy converted into kinetic energy of pulsation. This process is similar to what goes on with any heat engine, in which heat is absorbed in the high temperature phase of oscillation and emitted when the temperature is low. The main mechanism for stars is the net conversion of radiation energy into pulsational energy in the surface layers of some classes of stars. The resulting oscillations are usually studied under the assumption that they are small, and that the star is isolated and spherically symmetric. In binary star systems, stellar tides can also have a significant influence on the star's oscillations. One application of asteroseismology is neutron stars, whose inner structure cannot be directly observed, but may be possible to infer through studies of neutron-star oscillations.

2 Wave types

Waves in Sun-like stars can be divided into three different types;[4]

- p-mode: Acoustic or pressure (p) modes,[2] driven by internal pressure fluctuations within a star; their dynamics being determined by the local speed of sound.
- g-mode: Gravity (g) modes, driven by buoyancy,[5]
- f-mode: Surface gravity (f) modes, akin to ocean waves along the stellar surface.[6]

Within a Sun-like star, such as Alpha Centauri, the p-modes are the most prominent as the g-modes are essentially confined to the core by the convection zone. However, g-modes have been observed in white dwarf stars.[5]

3 Solar seismology

Helioseismology, also known as Solar seismology, is the closely related field of study focused on the Sun. Oscillations in the Sun are excited by convection in its outer layers, and observing solar-like oscillations in other stars is a new and expanding area of asteroseismology.

4 Space missions

A number of active spacecraft have asteroseismology studies as a significant part of their mission.

- MOST – A Canadian satellite launched in 2003. The first spacecraft dedicated to asteroseismology.
- COROT – A French led ESA planet-finder and asteroseismology satellite launched in 2006
- WIRE – A NASA satellite launched in 1999. A failed infrared telescope now used for asteroseismology.
- SOHO – A joint ESA / NASA spacecraft launched in 1995 to study the Sun.
- Kepler – A NASA planet-finder spacecraft launched in 2009 that made asteroseismology studies of over a thousand stars in its field, including the now well-studied subgiant KIC 11026764.[7][8]

5 Red giants and asteroseismology

Red giants are a later stage of evolution of Sun-like stars after the core hydrogen fusion ceases as the fuel runs out. The outer layers of the star expand by about 200 times and the core contracts. However, there are two different stages, first one when there is fusion of hydrogen in a layer outside the core, but none of helium in the core, and then a later stage when the core is hot enough to fuse helium. Previously, these two stages could not be directly distinguished by observing the star's spectrum, and the details of these stages were incompletely understood. With the Kepler mission, asteroseismology of hundreds of relatively nearby red giants[9] enabled these two types of red giant to be distinguished. The hydrogen-shell-burning stars have gravity-mode period spacing mostly ~50 seconds and those that are also burning helium have period spacing ~100 to 300 seconds. It was assumed that, by conservation of angular momentum, the expansion of the outer layers and contraction of the core as the red giant forms would result in the core rotating faster and the outer layers slower. Asteroseismology showed this to indeed be the case[10] with the core rotating at least ten times as fast as the surface. Further asteroseismological observations could help fill in some of the remaining unknown details of star evolution.

6 References

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[7] Metcalfe, T. S.; et al. (2010-10-25). "A Precise Asteroseismic Age and Radius for the Evolved Sun-like Star KIC 11026764". *The Astrophysical Journal* **723** (2): 1583. arXiv:1010.4329. Bibcode:2010ApJ...723.1583M. doi:10.1088/0004-637X/723/2/1583.

[8] "Graphics for 2010 Oct 26 webcast – Images from the Kepler Asteroseismology Science Consortium (KASC) webcast of 2010 Oct 26". NASA. 2010-10-26. Retrieved 3 November 2010.

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7 External links

- Asteroseismology.org
- Kepler Asteroseismic Science Operations Center (KASOC)
- Stellar Oscillations Network Group (SONG)
- European Helio- and Asteroseismology Network (HELAS)
- Asteroseismology for Galactic Archaeology (SAGA)

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